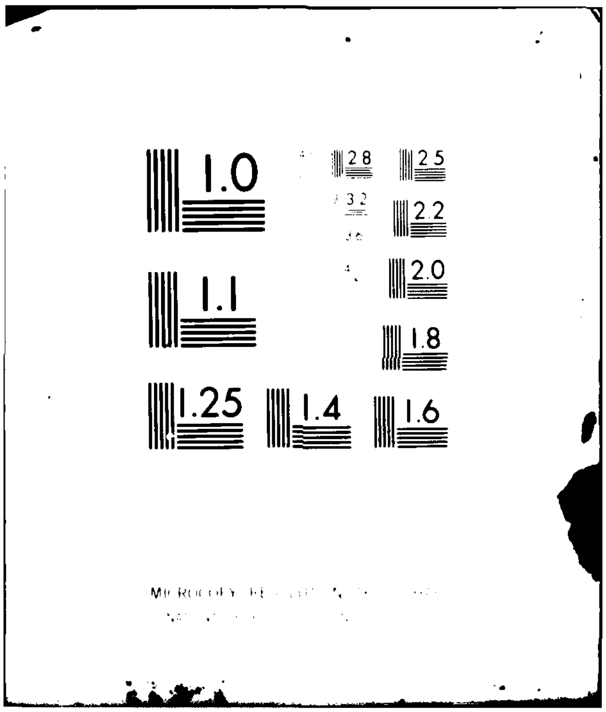
AD-A098 278 OHIO STATE UNIV COLUMBUS DEPT OF AGRONOMY F/G 8/13
THE EFFECTS OF REDUCED TILLAGE ON PHOSPHATE TRANSPORT FROM AGRI--ETC(U)
JAN 81 T J LOGAN, J R ADAMS DACW49-80-C-0015

UNCLASSIFIED NL

1 of 1

END
DATE
FILMED
5-81
DTIC


1.0
2.8
2.5
3.2
2.2
3.6
2.0
1.1
1.8
1.25
1.4
1.6

TECHNICAL REPORT SERIES

THE EFFECTS OF REDUCED TILLAGE ON PHOSPHATE TRANSPORT FROM AGRICULTURAL LAND

PREPARED FOR THE
LAKE ERIE WASTEWATER
MANAGEMENT STUDY
U.S. ARMY ENGINEER DISTRICT, BUFFALO

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER (6)

2. GOVT ACCESSION NO. AD-A098278

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
The Effects of Reduced Tillage on Phosphate Transport from Agricultural Land.

5. TYPE OF REPORT & PERIOD COVERED
(9) Final rept.

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
(10) Terry J./Logan
John R./Adams

8. CONTRACT OR GRANT NUMBER(s)
(15) DACW49-80-C-0015

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Logan-Agronomy Dept., Ohio State University
Adams-U.S. Army Engr District, Buffalo, N.Y. 14207

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Water Quality Section NCBED-HQ
U.S. Army Engineer District, Buffalo
1776 Niagara Street, Buffalo, N.Y. 14207

12. REPORT DATE
(11) Jan 81

13. NUMBER OF PAGES
29

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)
(12) 34

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for Public Release; Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES
Copies are available from National Technical Information Service, Springfield, VA 22161

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Conservation Tillage
Soil Loss
Phosphorus Loss
Surface Runoff

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report examines and summarizes published and some unpublished data on the relative effects of conservation tillage (primarily no till) versus conventional tillage on surface runoff, soil loss and phosphorus loss. The data show that conservation tillage increased runoff relative to conventional tillage on soils with poor internal drainage and reduced runoff on more permeable soils. Conservation tillage greatly reduced soil loss and total particulate P (TPP) loss, but the percent reduction of TPP was only 89% of the

percent reduction in soil loss. Conservation tillage increased soluble P (OP) losses in all cases. Conservation tillage was less effective in reducing plant-available (Bray P1) phosphate than in reducing TPP. P fertilization in excess of crop needs increased soluble P losses in runoff, and the effect of P fertilization on soluble P losses was greatest with no till because of P accumulation at the surface.

THE EFFECTS OF REDUCED TILLAGE ON PHOSPHATE TRANSPORT FROM AGRICULTURAL LAND

(12)

by

Terry J. Logan
Agronomy Department
The Ohio State University

and

John R. Adams
Corps of Engineers

January 1981

Lake Erie Wastewater Management Study
U.S. Army Corps of Engineers, Buffalo District
1776 Niagara Street
Buffalo, N.Y. 14207

TABLE OF CONTENTS

LIST OF TABLE AND FIGURES

Page

Tables

Figures

ABSTRACT

This report examines and summarizes published and some unpublished data on the relative effects of conservation tillage (primarily no till) versus conventional tillage on surface runoff, soil loss and phosphorus loss. The data show that conservation tillage increased runoff relative to conventional tillage on soils with poor internal drainage and reduced runoff on more permeable soils. Conservation tillage greatly reduced soil loss and total particulate P (TPP) loss, but the percent reduction of TPP was only 89% of the percent reduction in soil loss. Conservation tillage increased soluble P (OP) losses in all cases. Conservation tillage was less effective in reducing plant-available (Bray P1) phosphate than in reducing TPP. P fertilization in excess of crop needs increased soluble P losses in runoff, and the effect of P fertilization on soluble P losses was greatest with no till because of P accumulation at the surface.

INTRODUCTION

The Lake Erie Wastewater Management Study (LEWMS) has determined that conservation tillage practices can significantly reduce gross erosion from cropland in the Lake Erie basin (Corps of Engineers, 1979), and that this reduction can be achieved with no loss of crop yield if conservation tillage is only used on those soils for which the practice is suited (Forster, 1979). It is assumed this reduction in gross erosion will also significantly reduce the diffuse phosphorus load to Lake Erie, an assumption that is based on the fact that ∿ 80% of the total tributary phosphorus load to the lake is sediment-bound P (hereafter referred to as total particulate phosphate - TPP) and that ∿ 70% of the diffuse phosphorus tributary load is from agricultural land use. In its estimate of P reduction with conservation tillage, LEWMS assumed that these practices would only be 60-90% as effective in reducing P as in reducing erosion. This range of effectiveness was based on data from a few studies (Corps of Engineers, 1979) and was applied to the total phosphate load rather than just TPP.

This report examines the available literature on effects of tillage on soil and nutrient losses, and addresses the following specific questions:

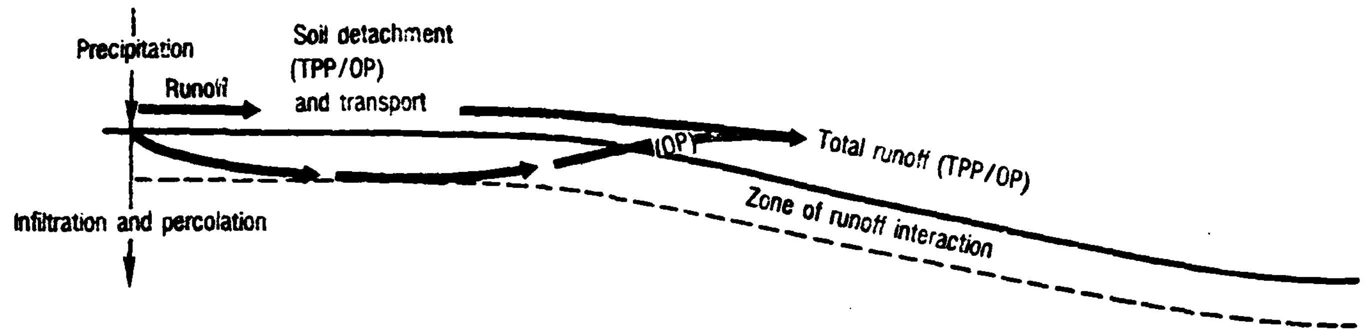
1. What is the relationship between erosion, TPP loss and soluble P loss (hereafter referred to as orthophosphate, OP)?
2. The effect of conservation tillage systems (no-till, chisel plow, etc.) on soil loss and TPP and soluble P losses.
3. Effect of reduced tillage on infiltration and runoff.
4. Effect of P fertilization practices on loss of available and soluble P in runoff.

CONCEPTUAL RELATIONSHIPS BETWEEN SOIL, TPP AND SOLUBLE P

Phosphate exists in the soil as soluble and particulate phases as well as in several chemical forms. During runoff, erosion and sediment transport, several reactions occur simultaneously. These are visualized in Figure 1.

1. Precipitation strikes the soil surface and a fraction infiltrates while another portion runs off.
2. Part of the water that infiltrates continues to percolate downwards and part reacts with only a shallow zone of soil below the surface before leaving the field in the runoff. This zone of runoff interaction is probably < 1 cm (Personal communication with Dr. Andy Sharpley, USDA-AR, Durant, Oklahoma).
3. Precipitation striking the soil surface dislodges soil particles and runoff carries some of the eroded soil downslope with only a fraction actually leaving the field as sediment. During the erosion and sediment transport process, there is a selective removal of clay and organic matter, and both of these materials contain higher levels of phosphorus than the coarser sand and silt fractions. As erosion is reduced by conservation tillage (e.g. no-till), the sediment that is lost from the field becomes progressively more enriched in clay and organic matter and the phosphorus enrichment ratio increases (Figure 1a). Therefore, the percentage reduction in TPP with conservation tillage will be less than the percentage reduction in soil loss.
4. As water reacts with the soil surface (the zone of interaction), soluble P held in soil pores is removed, water soluble soil

PHOSPHORUS TRANSPORT IN RUNOFF



Total Particulate Phosphate (TPP) Transport

Selective transport of clay and organic matter in runoff gives sediment that is enriched in phosphate; proportion of clay in sediment increases as soil loss decreases, which increases phophorus enrichment (Figure a).

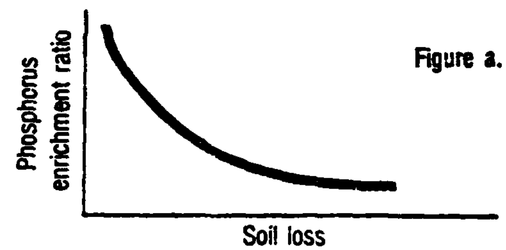


Figure a.

Soluble Phosphate (Orthophosphate, OP) Transport

Soluble P in runoff includes P held in soil pores in the zone of runoff interaction, dissolution of soluble P compounds in the soil, P leached from decomposing surface plant residues and desorption of P adsorbed on soil particles. Soluble P equilibrates with sediment in runoff by adsorption/desorption (Figure b).

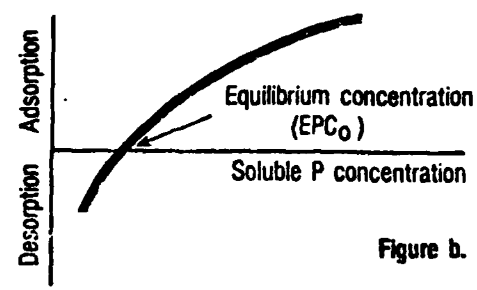


Figure b.

Figure 1. A conceptual view of phosphorus transport in runoff from agricultural land.

phosphorus compounds are dissolved and some of the inorganic P sorbed on soil surfaces is desorbed into the water. Also, some soluble P is contributed from decaying crop residues especially in no till systems.

5. The final concentration of soluble P in runoff leaving the field will be determined by the equilibrium between soluble P and the sediment, and the characteristics of the equilibrium isotherm (Figure 1b). are dependent on such properties as fertilizer use, soil loss, soil chemical characteristics, etc. These will be discussed later.

Runoff produced by excessive precipitation erodes and transports soil and the particulate and soluble P associated with that soil. Because of the high affinity of soil for soluble P, most of the P in runoff is particulate. Figure 2 shows, for example, that storms which generated soil loss for a 1-ha watershed in Michigan (Ellis et al., 1978) also transported TPP and OPP, but TPP increased more rapidly with increasing soil loss than did OP. The question that will be examined in this report is to what extent are TPP and OP reduced when conservation tillage is used to reduce soil loss, and are there other management factors such as phosphate fertilization which affect P losses in runoff?

EFFECT OF CONSERVATION TILLAGE ON RUNOFF

Plant residue on the soil surface serves to protect the soil from raindrop impact and will help prevent soils with poor surface structure from crusting and sealing. Residue also increases surface roughness compared to conventional clean tilled soil, and these factors should give increased infiltration and reduced runoff with no till or other tillage

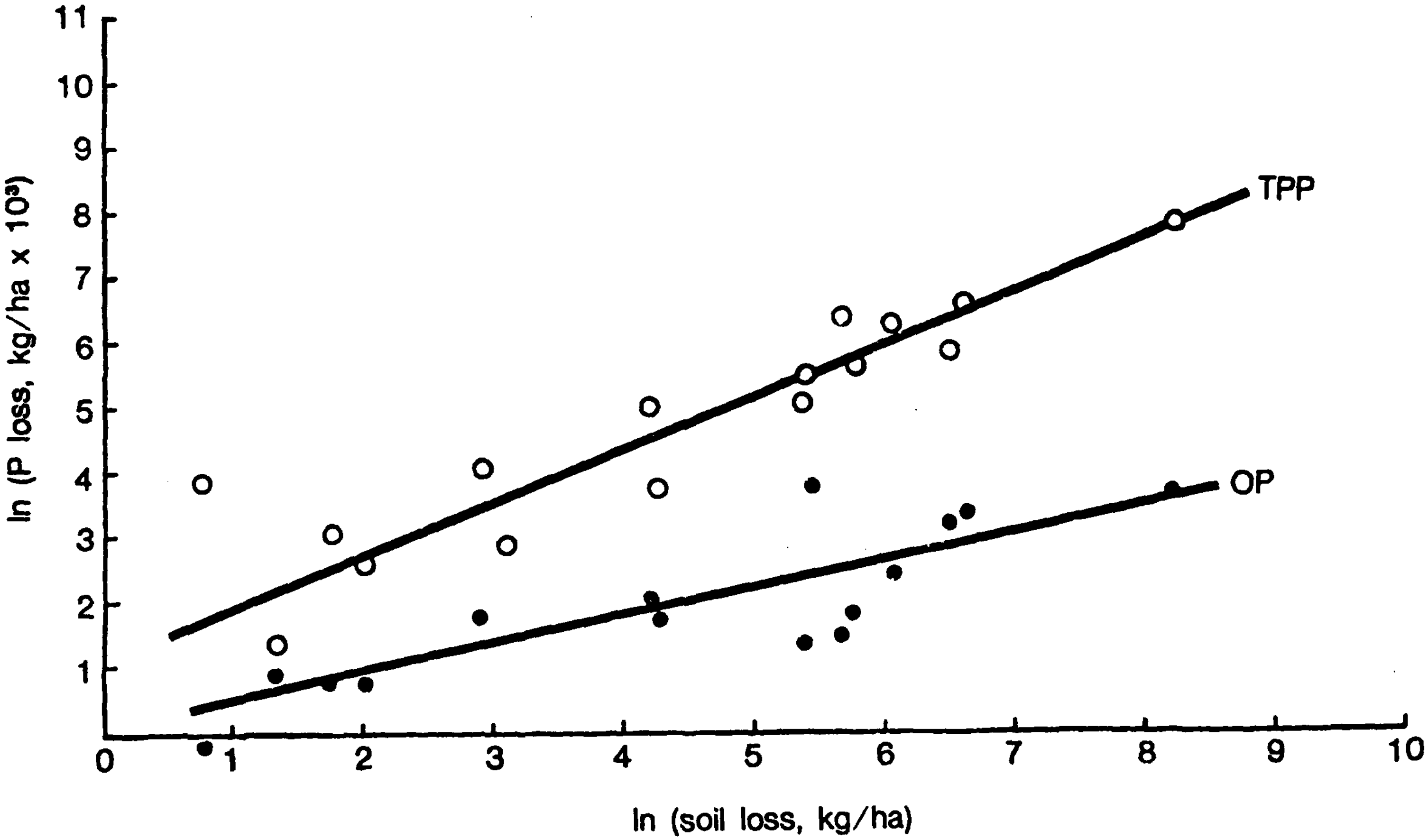


Figure 2. Relationship between soil loss and total particulate P (TPP) and soluble P (OP) in runoff. Derived from the data of Ellis et al. (1978).

systems which maintain a high degree of cover. On the other hand, significant roughness is achieved with moldboard plowing, especially in the fall, and Johnson and Moldenhauer (1979) have recently shown good infiltration and lower runoff when soils were plowed at optimum moisture contents.

Data from several studies varying in scale from rainfall simulator plots to small watersheds (< 1 ha) were examined and the results summarized in Table 1 and Figure 3. In Figure 3, runoff from no till or till plant systems were plotted against runoff from the conventional tillage treatment. Only studies where tillage treatments were compared at the same location at the same time were included. Figure 3 shows that soils which have poor internal drainage or restricted subsurface drainage gave <u>higher</u> runoff with no till than with conventional tillage. Soils which are permeable and do not have restricted subsurface drainage had higher runoff with conventional tillage.

There are several factors which probably control the effect of tillage on runoff:

Soils which have restricted drainage may be saturated during periods of high precipitation, and the increased infiltration capacity afforded by the rougher, more open, no till surface cannot be utilized. In the Corn Belt where winter and early spring rains contribute much of the annual runoff, the roughness and surface storage capacity provided by fall moldboard plowing may be more important in reducing runoff than the effects of no till residue. No till may reduce runoff on more permeable soils by reducing the crusting which can occur with conventional tillage.

In the Lake Erie drainage basin, no till will probably either increase runoff or have little effect, except on some well drained soils where runoff may

Table 1. Effect of conservation tillage versus conventional tillage on surface runoff (the crop is corn except where noted otherwise).

Tillage	Precipitation	Runoff	Comments	Reference
	---------cm/yr-------			
Conventional	48.7	4.3		Johnson et al (1979)
Till plant	48.7	2.0		"
Conventional	12.7	10.1	Simulated rainfall	Romkens et al (1973)
No Till	12.7	7.4		"
Conventional (1970)	81.8	15.4	"	Schwab et al (1973)
No Till (1970)	81.8	17.8	"	"
Conventional (1971)	68.9	8.8	"	"
No Till (1971)	68.9	8.7	"	"
Conventional	15.4*	6.4	Soybeans	McDowell and McGregor (In Press)
No Till	15.4*	4.6	"	"
Conventional	118.0	28.3	"	"
No Till	118.0	13.0	"	"
Conventional	169.0	83.2	"	"
No Till	169.0	42.8	"	"
Conventional	67.9	5.7	Soybeans	Logan and Stiefel (1979)
No Till	67.9	6.8	"	"
Conventional	6.6	2.5	Simulated rainfall	Mannering et al (1966)
Minimum Tillage	6.6	3.6		"
Conventional	11.1	9.3	Simulated rainfall	Triplett et al (1968)
No Till (40% residue cover)	11.1	8.7		"
Conventional (1974)	96.5	13.5		Smith et al (1979)
No Till (1974)	96.5	17.5		"
Conventional (1975)	103.3	17.5		"
No Till (1975)	103.3	22.6		"
Conventional (1976)	54.9	5.8		"
No Till (1976)	54.9	5.6		"
Conventional (1977)	96.3	8.3		"
No Till (1977)	96.3	11.2		"

* For the period May-June only.

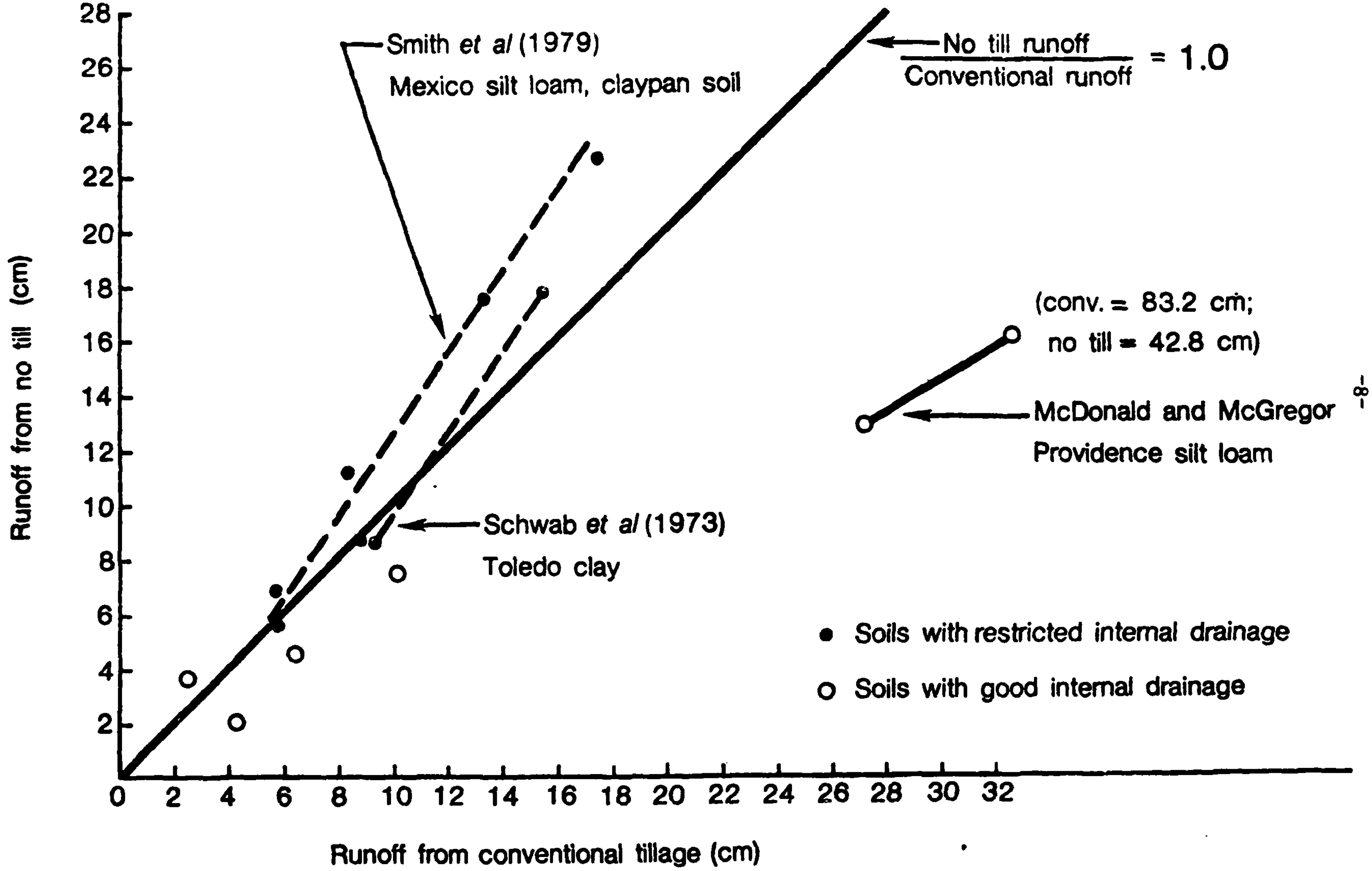


Figure 3. Relationship between runoff from no till (or conservation tillage) and conventional tillage plots for several field studies, with natural or simulated rainfall. (All points not specifically identified were from silt loam soils).

decrease slightly with no till. In terms of stream flow, however, there is not likely to be much effect of tillage since much of the percolation in the major crop producing areas is intercepted by tile drainage systems or seepage and returned to the stream.

EFFECT OF CONSERVATION TILLAGE ON REDUCTION OF TOTAL PARTICULATE PHOSPHATE

Table 2 summarizes erosion and phosphorus losses form agricultural land with conservation tillage and conventional tillage. The studies reported here include rainfall simulator plots, field plots and small watersheds. Table 2 shows dramatically the great reduction in soil loss that can be achieved with conservation tillage systems including no till. The data also show a significant reduction in TPP with conservation tillage. In Figure 4, the percent reduction in soil loss was plotted against the percent reduction in TPP. The line plotted through the points has a somewhat lower slope than the 1:1 line. In fact, the slope was 0.89 which means that conservation tillage is 89% as effective in reducing TPP as in reducing soil loss. This compares favorably with the high value of 90% assumed in the LEWMS Phase II Report (1979) rather than the lower value of 60%.

This less than 100% efficiency in reducing TPP is a result of the phosphorus enrichment ratio relationship with soil loss shown in Figure 1b. Sharpley (1980) and Menzel (1980) have recently shown that there is a logarithmic relationship between phosphorus enrichment ratio (PER) and sediment load (kg/ha):

$$\ln(\text{PER}) = 2.00 - 0.20 \ln(\text{sediment load}) \quad \text{(Menzel, 1980)}$$

$$\ln(\text{PER}) = 2.48 - 0.27 \ln(\text{sediment load}) \quad \text{(Sharpley, 1980)}$$

Table 2. Loss of sediment, total particulate phosphate (TPP) and soluble orthophosphate (OP) with conventional and conservation tillage (crop was corn except where noted otherwise).

Tillage	Precipitation (cm)	Runoff (cm)	Sediment (kg/ha)	TPP (kg/ha)	OP (kg/ha)	Comments	References
Conventional	48.7	4.3	18,000	38.88	0.12	Values estimated	Johnson *et al*
Till Plant	"	2.0	4,000	10.85	0.15	from graphs	(1979
Conventional	46.8	11.7	2,004	1.90	0.05	Two different	Logan
No till	75.3	13.8	74	0.32	0.09	years on same plot	(unpublished)
Conventional	12.7	10.1	46,120	15.48	0.002	Simulated	Romkens *et al*
No Till	"	7.4	3,470	2.11	0.009	rainfall	(1973)
Conventional (NY)	--	10	20,000	33	0.15	Model output	Haith and
Cons. tillage (NY)	--	8	9,000	15	0.11	using field	Loehr (1979)
Conventional (Iowa)	--	7	17,000	23	0.24	data	"
Cons. tillage (Iowa)	--	5	5,000	17	0.16	"	"
Conventional (Ga)	--	19	41,000	17	0.39	"	"
Cons. tillage (Ga)	--	16	24,000	10	0.32	"	"
Conventional (1970)	81.8	15.4	1,749	8.3	0.20		Schwab *et al*
No Till (1970)	"	17.8	438	0.4	1.70	"	(1973)
Conventional (1971)	68.9	8.8	772	1.2	0.10		
No Till (1971)	"	8.7	273	1.3	0.20		
Conventional	15.4	6.4	25,300	13.5	0.001	Soybeans	McDowell and
Continuous No Till	"	4.6	60	0.19	0.93	"	McGregor
Soybeans-wheat No Till	"	0.3	5	0.02	0.03		(In Press)
Soybeans-corn No Till	"	7.7	530	1.17	0.28		"
Corn-soybeans No Till	"	6.1	340	0.82	0.98		"
Conventional	96*	11.8	3,570	--	0.16	Mean of	Smith *et al*
No Till	"	15.4	470	--	1.56	seven years data	(1979)

* Mean precipitation for 84 years of record.

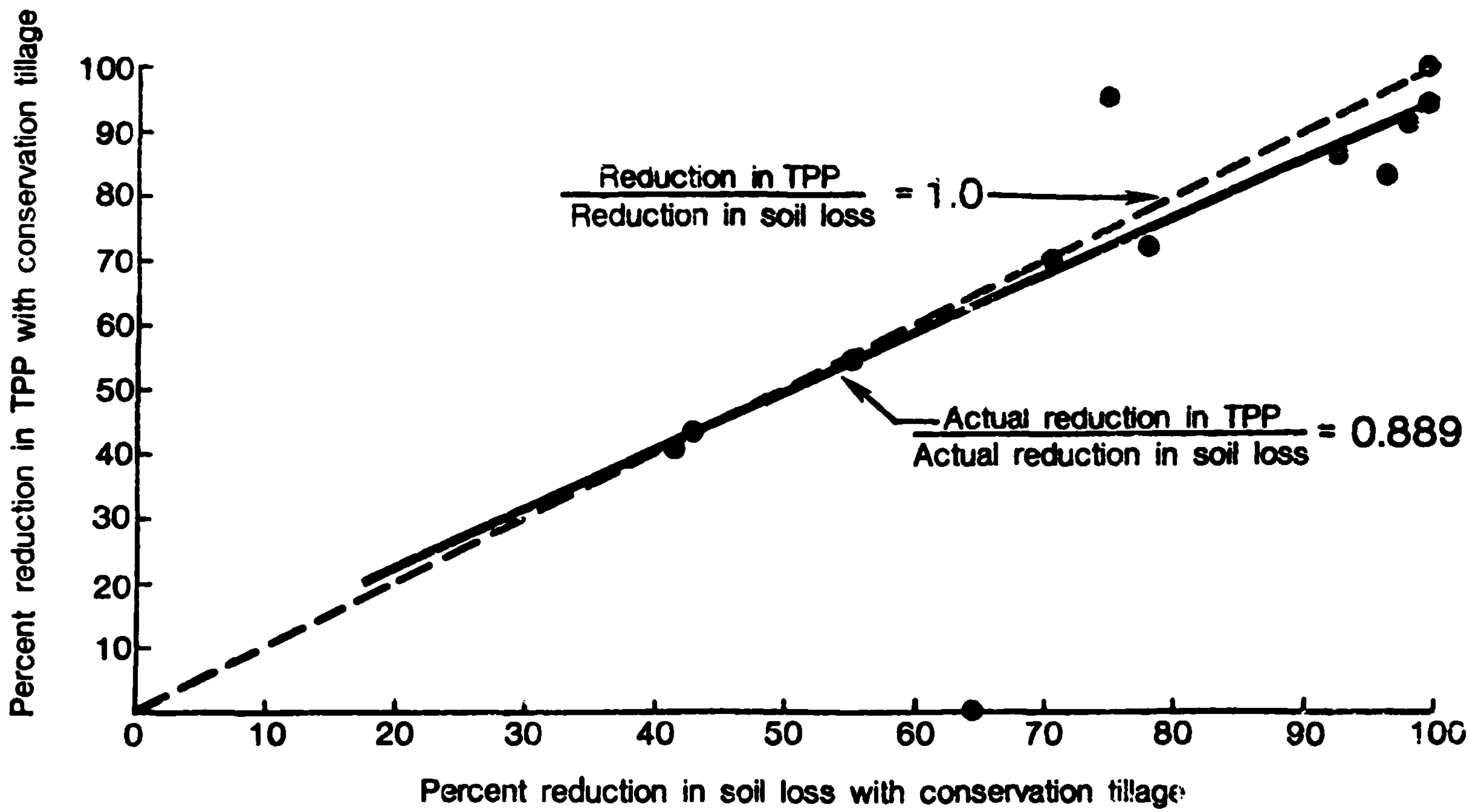


Figure 4. Reduction in total particulate P (TPP) with conservation tillage as a function of soil loss reduction.

If we assume a value of 700 μg P/g as an average concentration for Lake Erie basin soils (Logan, 1978), we can use the above equations to predict reduction in TPP with erosion control. In Table 3, total particulate phosphate load (TPP) has been calculated for 1, 5 and 10 metric tons/ha of sediment loss and the phosphorus reduction efficiency calculated by using the 10 mt/ha sediment load as the level of sediment before control. This gives a percentage efficiency between 80 and 94%, similar to the 89% found for field monitored data (Figure 4).

EFFECT OF CONSERVATION TILLAGE ON REDUCTION OF SOLUBLE INORGANIC PHOSPHORUS IN RUNOFF

As indicated in Figure 2, runoff does not transport as much soluble P as it does TPP, and soluble P (OP) does not increase with increasing runoff as much as TPP does. As discussed previously, this is related to the buffering of OP by the sediment during runoff.

In the case where no till is used, Table 2 shows that there is a great reduction in sediment load with only minor changes in runoff volume compared to conventional tillage. Table 2 also shows that, whereas TPP was reduced proportionally with the reduction in sediment, soluble P (OP) <u>increased</u> in all cases (excluding the data of Haith and Loehr, 1980 which is a computer generated output and may have been based on erroneous assumptions). There are several reasons for this effect. In a non-equilibrium soil, such as a fertilized soil where the phosphate added has not reacted completely with the soil minerals, there are significant amounts of soluble P held in soil pores, precipitated as soluble compounds or adsorbed on soil surfaces (Figure 1). During runoff some of this soluble P is removed and comes to equilibrium (or near equilibrium) with the sediment in the runoff. When

Table 3. Calculated phosphorus loads and phosphorus reduction efficiencies using the PER/sediment load equations of Menzel (1980) and Sharpley (1980).

Sediment Load	Phosphorus Load		Phosphorus Reduction Efficiency (percent)	
kg/ha				
	Menzel	Sharpley	Menzel	Sharpley
10,000	8.19	6.95	--	--
5,000	4.71	4.19	85.0	79.4
1,000	1.30	1.29	93.5	90.5

no till is used, the amount of sediment in the runoff decreases dramatically but the runoff volume is little changed. Therefore, the amount of soluble P initially removed during runoff is similar to that with conventional tillage; but there is less sediment in the no till runoff to buffer the soluble P load and it, therefore, increases relative to conventional tillage. Another reason for higher soluble P levels with no till is the buildup of fertilizer P on the surface of no till soils (discussed in the next section) and the leaching of soluble P from decaying plant residues. McDowell et al. (1980) examined the equilibrium P concentrations (EPC_o) of no till soils in Mississippi with corn grown for grain and for silage. EPC_o as shown in Figure 1 is a measure of soluble P concentrations in runoff, and McDowell, et al (1980) reported EPC_o values of 0.18 and 0.22 μgP/ml for grain plots and 0.15 and 0.15 μgP/ml for the silage plots where much of the corn stalks are removed at harvest. In addition, losses of soluble P in the fall and winter period from spring-plowed plots were 0.426 kg/ha for the corn grain plots and 0.195 kg/ha for the silage plots.

These results indicate that while no till can be expected to greatly decrease soil loss on land previously tilled, the main effect on phosphorus loads will be to significantly decrease the particulate P with no change or an increase in soluble P. If this is true, then other management options for controlling soluble P must be considered including fertilizer use.

EFFECT OF PHOSPHATE FERTILIZATION ON LOSSES OF AVAILABLE AND SOLUBLE P IN RUNOFF

When fertilizer P is added to soil, it is generally 100% orthophosphate, 100% available. It reacts immediately with the small volume of soil that it contacts and much of it is rendered insoluble and unavailable.

Long-term soil fertility research has shown that only about 10-20% of the fertilizer P remains available after addition. The unavailable forms include highly insoluble precipitates of P with soil-containing cations such as Fe, Al, Mg, Ca and others, and P which has sorbed and diffused into soil mineral surfaces. The available forms include soluble P in soil pores and labile P sorbed onto soil surfaces. The chemistry and mineralogy of a particular soil will determine the extent to which fertilizer P is converted to available and unavailable forms, and the distribution of P between these forms will affect the amounts of TPP and OP in runoff. But for a particular soil, any increase in P fertilizer over and above the needs of the crop will increase the levels of available P in the soil and the levels of soluble P as well.

Since P fertilization above crop removal will increase the total P level in the surface soil, it should also increase TPP losses in runoff if erosion remains the same. More important, however, is the effect of P fertilization on the loss of "available" TPP. In the studies reported here, "available" means available to crops and is determined by a standard chemical extraction such as Bray P1 (Bray and Kurtz, 1945). However, it also reflects the pool of TPP that would be available to algae. Lake and Morrison (1975) reported on a simulated rainfall study of fertilized and unfertilized Indiana soils. The data (Table 4) show that while TPP in runoff increased with fertilization, the increase in Bray P1 available sediment P losses was much greater and can be explained by the higher available P levels of the clay fraction of the soils, the fraction that is selectively transported during runoff.

Table 4. Runoff losses of TPP and Bray P1 extractable sediment P under simulated rainfall (Lake and Morrison, 1975).

Soil	Treatment	Runoff		Bray P1 extractable P	
		TPP	Bray P1	Whole Soil	Clay
		μg/g			
Haskins loam	Unfertilized	530	76	46	155
	Fertilized	643	213		
Nappanee clay loam	Unfertilized	267	113	44	75
	Fertilized	547	199		
Morley clay loam	Unfertilized	553	25	12	16
	Fertilized	665	196		
Hoytville silty clay	Unfertilized	1230	231	117	166
	Fertilized	1375	368		

Similarly, Table 5 shows that, where P was applied in excess of crop needs (Smith et al., 1979), Bray P1 sediment P losses increased, and the increase was greatest with no till. Table 5 also gives the data of Johnson et al. (1979) which showed an increase in Bray P1 sediment P in one case where soil loss was reduced with conservation tillage and, in the other case, only a 74% reduction compared to the > 90% reduction in TPP for the same study (Table 2).

Relationship Between P fertilization and Soluble P in Runoff

Fertilizer P increases the available P level in soil and soluble P in soil pores. Also, at higher available P levels the equilibrium between adsorbed P and P in solution is shifted towards higher concentrations. If runoff volume and soil loss remain the same, P fertilization in excess of crop needs should increase soluble P losses in runoff. Several researchers have clearly demonstrated this relationship using different approaches. Romkens and Nelson (1974) found a highly significant positive linear relationship between soluble P concentrations in runoff and Bray P1 extractable P of the sediment, and McDowell et al., (1980) found that several available P tests including Bray P1 and Olsen's bicarbonate (Olsen et al., 1954) were correlated with EPC_o, a measure of soluble P concentrations of water in equilibrium with sediment.

Oloya and Logan (1980) recently examined the desorption of soluble P from soils and sediments with a wide range of Bray P1 extractable P levels and found that there was a highly significant positive relationship; about 5-10% of the available P could be desorbed in a 24-hr. period.

Table 5. Loss of Bray P1 extractable (plant-available) P with conventional tillage and conservation tillage (the crop was corn in all cases).

Tillage		Soil Loss	Bray P1 extractable sediment P	References
		----------kg/ha	----------	
Recommended P	Conventional	3,430	0.17	Smith et al (1979)
"	No till	500	0.03 (96.4)*	"
Recommended P	Conventional	3,430	0.28	"
plus 98 kgP/ha/yr	No till	500	0.94 (Increase)	"
1974	Conventional	57,000	1.1	Johnson _et al_ (1979)
1974	Till plant	24,000	1.4 (Increase)	"
1975	Conventional	19,000	0.7	"
1975	Till plant	8,000	0.4 (74.0)	"

* Reduction of extractable P as a percentage of soil loss reduction.

Effect of Fertilizing No Till Soils on Soluble P Losses

No till soils are commonly fertilized by broadcasting on the soil surface, or as a starter application with the planter if available P levels are high enough. Since the soil is not disturbed and since fertilizer P reacts rapidly with the small volume of soil it contacts, P braodcast on the surface of no till soils will accumulate there. This is illustrated by the data of Oloya and Logan (1980) given in Table 6. A total of 268 kgP/ha was applied to no till and conventional plots over a four-year period. This increased Bray P1 available P from 18 μg P/g prior to fertilization to about 50 μg/g in the 15 cm depth of the fall-plowed plots and to 150-184 μg/g in the 0-5 cm depth of the no till plots. This increase resulted in increased desorbable P from these soils (Table 6) and the monitoring data (unpublished) indicate that soluble P levels in the runoff have also increased steadily, with the greatest increases from the no till plots.

Romkens et al. (1973) used simulated rainfall to study runoff from fertilized and unfertilized plots with different tillage systems. No till and chisel plowing reduced soil loss compared to conventional plow systems but soluble P losses were higher with the no till system. The fertilized no till plot had 4.85 kgP/ha soluble P loss compared to 0.003 kg/ha with the fertilized conventional plowing. This study has been criticized because the simulated rain was applied only 24 hours after fertilizer application, but it nevertheless demonstrates the potential for loss of soluble P when fertilizer is broadcast on no till soil.

Baker and Laflen (1980) also used simulated rainfall to study movement of fertilizer P with residue management. They found that placement of

Table 6. Bray P1 extractable P and P desorbed for Hoytville soil from tillage experiment at Hoytville, Ohio (Oloya and Logan, 1980).

	Depth (cm)	Bray P1 Extractable P	P Desorbed
		---------------ugP/g---------------	
Zero P addition	0-15	18.1*	2.8
Fall plowed	0-5	46.6	4.7
	5-15	59.3	6.3
	15-30	18.1	1.1
	30-60	1.8	0.9
No Till I	0-5	152.1	39.1
	5-15	38.7	3.7
	15-30	14.9	0.9
	30-60	5.0	0.7
No Till II	0-5	183.9	43.7
	5-15	29.3	1.9
	15-30	22.6	1.6
	30-60	4.1	0.7

* Extractable P and P desorbed are means of duplicate extractions.

fertilizer P on the soil surface either above or below the crop residue gave much higher soluble P losses than nonfertilized plots or plots where the fertilizer was injected below the soil surface. Their work showed that the major problem was the accumulation of fertilizer P at the surface and not necessarily the degree to which the fertilizer reacted with the soil prior to rainfall. This is probably because, as Oloya and Logan (1980) have shown, surface-applied fertilizer P builds up very high levels of available P at the soil surface and part of this is desorbed during runoff to become soluble P.

IMPLICATIONS FOR AVAILABLE PHOSPHORUS CONTROL WITH NO TILL

Several workers have studied the bioavailability of TPP in Great Lakes tributary sediments (Cowen and Lee, 1976; Logan et al., 1979; Armstrong et al., 1979) and they show that about 20% of TPP is available with a range of about 10-50%. If we arbitrarily assume that P losses from Lake Erie cropland prior to adoption of conservation tillage are 2.0 kgP/ha TPP and 0.2 kg/ha OP, then based on previous discussion in this report on no till effectiveness, TPP may be reduced by 90% to 0.2 kgP/ha and OP would be unchanged at 0.2 kg/ha. This represents a percentage reduction of (TPP + OP) of 81.8%, but if we assume that the TPP is 20% available and OP is 100% available, then the reduction in total available P is only 60%. If, as the data (Table 2) has shown, there is actually an increase in OP with no till, then these percentages will be lower and the reduction in available P may be in the range of 30%.

If decreases in available P greater than 30% are required, then no till alone will not be adequate. This report has shown, however, that there is

a strong relationship between P fertilization practices and loss of both available TPP and also OP in runoff. Therefore, P fertilization management may be required. Management practices which could reduce available P losses with no till include:

1. Keep available P levels in the soil no higher than is necessary for optimum crop production. This requires an annual soil test to monitor soil fertility levels.
2. If soil test levels are above the sufficiency level (Ohio Agronomy Guide, 1980), a row fertilizer which is placed in the soil with the seed should be used.
3. If soil test levels are below the sufficiency level, two options are possible: build-up the level by broadcasting P and plowing it in before going to no till; or build the level up more slowly with small annual broadcast applications and a row fertilizer and then plow after several years of no till to incorporate the added P to lower depths.

CONCLUSIONS

1. No till dramatically reduces soil loss (> 90% reduction) compared to conventional plow systems.
2. No till increases runoff compared to conventional tillage with soils that have poor internal drainage or have restricted subsurface drainage, while no till decreases runoff on soils that are more permeable.
3. No till is about 89% as effective in reducing TPP loss as it is in reducing soil loss.
4. Soluble P (OP) loss increases with no till compared to conventional tillage.
5. Available TPP loss decreases less with no till than does TPP.
6. Available TPP loss increases with P fertilization.
7. There is a strong positive relationship between P fertilization or available P level of soil and soluble P loss in runoff.
8. P fertilizer broadcast on no till land increases soluble P losses in runoff more than if the fertilizer were incorporated.

REFERENCES

Armstrong, D.E., J.R. Perry and D. Flatness. 1979. Availability of pollutants associated with suspended or settled river sediments which gain access to the Great Lakes. Final Report. Wisconsin Water Resources Center, Madison.

Baker, J.L. and J.M. Laflen. 1980. Effect of corn residue and chemical placement on chemical runoff losses. Trans. Am. Soc. Agric. Eng. (In Press).

Bray, R.H. and L.T. Kurtz. 1945. Determination of total, organic and available forms of phosphorus in soils. Soil Sci. 59:39-45.

Corps of Engineers, Buffalo District. 1979. Lake Erie Management Study Methodology Report. Buffalo, N.Y. 146 pp.

Cowen, W.F. and G.F. Lee. 1976. Algal nutrient availability and limitation in Lake Ontario tributary waters. USEPA. Ecological Research Series. EPA-600/3-76-094a.

Ellis, B.G., A.E. Erickson and A.R. Wolcott. 1978. Nitrate and phosphorus runoff losses from small watersheds in Great Lakes Basin. EPA-600/3-78-028. USEPA Ecological Series, Envir. Res. Lab., Athens, Ga. 84 pp.

Forster, D.L. 1978. Economic impacts of changing tillage practices in the Lake Erie Basin. LEWMS Technical Report Series. Corps of Engineers, Buffalo District.

Haith, D.A. and R.C. Loehr. 1979. Effectiveness of soil and water conservation practices for pollution control. USEPA-RD. EPA-600/3-79-106. Environmental Research Laboratory, Athens, Ga. 474 pp.

Johnson, C.B. and W.C. Moldenhauer. 1979. Effect of chisel versus moldboard plowing on soil erosion by water. Soil Sci. Soc. Am. J. 43:177-179.

Johnson, H.P., J.L. Baker, W.D. Shrader, and J.M. Laflen. Tillage system effects on sediment and nutrients in runoff from small watersheds. Trans. Am. Soc. Agric. Eng. 22:1110-1114.

Lake, J. and J. Morrison. 1975. Environmental impact of land use on water quality. *Black Creek Progress Report.* USEPA Region V. EPA-905/9-75-006.

Logan, T.J. 1978. Levels of plant available phosphorus in agricultural soils in the Lake Erie Drainage Basin. LEWMS Technical Report Series. Corps of Engineers, Buffalo District.

Logan, T.J. and R.C. Stiefel. 1979. The Maumee River Basin Pilot Watershed Study. Vol. 1. Watershed characteristics and pollutant loadings. USEPA Region V. Great Lakes National Program Office. EPA-905/9-79-005-A. 135 pp.

Logan, T.J., T.O. Oloya, and S.M. Yaksich. 1979. Phosphate characteristics and bioavailability of suspended sediments from streams draining into Lake Erie. J. Great Lakes Res. 5:112-123.

Mannering, J.V., L.D. Meyer, and C.B. Johnson. 1966. Infiltration and erosion as affected by minimum tillage for corn (Zea mays L.) Soil Sci. Soc. Am. Proc. 30:101-105.

McDowell, L.L and K.C. McGregor. 1980. Nitrogen and phosphorus losses in runoff from no till soybeans. Trans. Am. Soc. Agric. Eng. (In Press).

McDowell, L.L., J.D. Schreiber and H.B. Pionke. 1980. Chapter 14. Estimating soluble (PO_4-P) and labile phosphorus in runoff from croplands. p.509-533. In Knisel, W.G. (ed). CREAMS: A field-scale model for chemicals, runoff and erosion from agricultural management systems. USDA Conservation Research Report. No. 26. 640 pp.

Menzel, R.G. 1980. Enrichment ratios for water quality modeling. Chapter 12. In Knisel, W.G. (ed). CREAMS: A field-scale model for chemicals, runoff and erosion from agricultural management systems. USDA Conservation Research Report. No. 26. 640 pp.

Ohio Agronomy Guide. 1980. Ohio Cooperative Extension Service, Columbus, Ohio. Bull. 472, 97 pp.

Oloya, T.O. and T.J. Logan. 1980. Phosphate desorption from soils and sediments with varying levels of extractable phosphate. J. Environ. Qual. 9:526-531.

Olsen, S.R., C.V. Cole, F. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circular 939.

Romkens, M.J.M. and D.W. Nelson. 1974. Phosphorus relationships in runoff from fertilized fields. J. Environ. Qual. 3:10-14.

Romkens, M.J.M., D.W. Nelson and J.V. Mannering. 1973. Nitrogen and phosphorus composition of surface runoff as affected by tillage methods. J. Environ. Qual. 2:292-295.

Schwab, G.O., E.O. McLean, A.C. Waldron, R.K. White and D.W. Michener. 1973. Quality of drainage from a heavy-textured soil. Trans. Am. Soc. Agric. Eng. 16:1104-1107.

Sharpley, A.N. 1980. The enrichment of soil phosphorus in runoff sediments. J. Environ. Qual. 9:521-526.

Smith, G.E., R. Blanchar and R.E. Burwell. 1979. Fertilizers and pesticides in runoff and sediment from claypan soil. Completion Report. B-099-MO, Missouri Water Resources Research Center, Columbia. 60 pp.

Triplett, G.B., D.M. Van Doren and B.L. Schmidt. 1968. Effect of corn (Zea mays L.) stover mulch on no tillage corn yield and water infiltration. Agron. J. 60:236-239.

DATE
ILMED
-8